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A COMPUTATIONAL INTELLIGENCE-BASED APPROACH FOR THE ANALYSIS OF THE HEALTH EXPENDITURE IN BRAZILIAN MUNICIPALITIES

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Abstract

This study aimed to analyze the health expenditures of Brazilian municipalities using computational intelligence, specifically through cluster analysis, to identify which municipalities have similar per capita expenditures relative to their GDP per capita. The research employs a quantitative and documentary approach, examining a sample of 117 Brazilian municipalities. These municipalities were grouped into clusters using the k-means method with the Euclidean similarity metric to identify patterns in public health spending, taking into account their economic realities. Data from the Brazilian Finance Bank (Finbra), adjusted for inflation, and cluster analysis conducted via R software were utilized. The findings revealed that disparities linked to the economic characteristics of municipalities significantly influence the correlations between health expenditures, although these correlations were less pronounced concerning primary care. By elucidating these results, the study contributes to the application of computational intelligence techniques in grouping municipalities and supports financial decision-making by municipal governments and public managers in the health sector.

Keywords: Cluster Analysis; Computational Intelligence; Public Health; Public Management.

Resumo

Este estudo teve como objetivo analisar os gastos com saúde dos municípios brasileiros utilizando inteligência computacional, especificamente por meio de análise de clusters, para identificar quais municípios têm despesas per capita semelhantes em relação ao seu PIB per capita. A pesquisa adota uma abordagem quantitativa e documental, examinando uma amostra de 117 municípios brasileiros. Esses municípios foram agrupados em clusters usando o método k-means com a métrica de similaridade euclidiana para identificar padrões nos gastos públicos com saúde, considerando suas realidades econômicas. Foram utilizados dados do Banco de Finanças do Brasil (Finbra), ajustados pela inflação, e análise de clusters realizada via software R. Os resultados revelaram que disparidades associadas às características econômicas dos municípios influenciam significativamente as correlações entre os gastos com saúde, embora essas correlações fossem menos pronunciadas em relação à atenção primária. Ao elucidar esses resultados, o estudo contribui para a aplicação de técnicas de inteligência computacional na agrupação de municípios e apoia a tomada de decisões financeiras por parte dos governos municipais e gestores públicos no setor da saúde.

Palavras-Chave: Análise de Cluster; Gestão Pública; Inteligência Computacional; Saúde Pública.

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INTRODUCTION

Efficient management of health resources has become a global priority for governments, particularly in countries with pronounced social inequalities, such as Brazil. Analyzing public expenditures is crucial not only because of its impact on the population's well-being but also due to its complexity and significant influence on public administration.

The Brazilian Public Administration, as a state apparatus, is fundamentally committed to developing public actions that benefit populations or communities by providing quality public services. Achieving high-quality public management requires guiding public administrators' conduct based on principles that have been essential since the 1988 Federal Constitution. These principles are not only applied in isolation but also interact with each other, necessitating careful attention and responsibility from managers when addressing public issues. This is particularly true in concrete situations that require the development of strategies through public planning. Given this fact, there is a need for the public manager to know the amount of available resources and, especially, the allocation of public spending, especially in the health area—which involves hospital care, primary care, general spending in the health sector—and by the function of the government object of this study, where computational intelligence becomes an ally in this discussion, both in the sense of supporting public managers in their internal decisions in each Brazilian municipality and in relation to the discussions related to the distribution of available resources, in the Health Commissions, together with other spheres of government. The computational intelligence-based approach in the analysis of public spending on health can offer important contributions to address these challenges. With the use of advanced data analysis techniques, such as cluster clustering, it becomes possible to identify spending patterns, optimize the allocation of resources, and improve the efficiency of the services offered to society. This methodology contributes to an understanding of the financial dynamics in this area, promoting more transparent and accountable administration.

Because of this, the use of computational intelligence as a decision support tool aligned with the responsibility of the public manager may present better control and transparency during the application and distribution of public resources to ensure that the three spheres of government, Union, States and Municipalities are as impartial as possible in relation to the rights of each federal entity, offering better financial conditions to those municipalities that face the greatest difficulties in health care.

In this context, this study aims to analyze the health expenditures of 117 Brazilian municipalities using a computational intelligence approach. By employing cluster analysis, it identifies which municipalities have similar per capita health expenses relative to their GDP per capita. The persistent

issue of limited financial resources makes municipalities increasingly responsible for public health spending, particularly evident in primary and secondary care services, which include outpatient procedures, and tertiary care, which encompasses hospital services and patient admissions.

Moreover, the lack of integrated information systems and computational intelligence hinders effective monitoring of expenses and outcomes, compromising transparency and data-driven decision-making. Therefore, it is crucial to discuss health management in these municipalities and explore how computational intelligence techniques can help identify spending patterns and optimize available resources in Brazilian public health. Without adequate tools for analysis and decision-making, public health managers struggle to meet their objectives, affecting the care and social well-being of the population.

To achieve the study's objectives, a quantitative and documentary approach was adopted. Initially, the 117 municipalities in the sample were grouped into clusters using the k-means method. This process took into account each municipality's public health expenditures and economic reality, measured by GDP per capita, to provide a comprehensive analysis of the results. The Euclidean similarity metric was employed to identify patterns and similarities among the municipalities, enabling a more precise and detailed examination of their economic and public health characteristics.

The main contribution of this study is based on the following premises: a) use of computational intelligence techniques to group municipalities in relation to their various public health expenditures to subsidize the financial decisions of municipal governments and managers in public health; b) the verification of the existence of a correlation between health expenditures in Brazilian municipalities considering the variables studied; c) and, finally, after a statistical analysis, to stimulate the debate on the distribution of health resources among Brazilian municipalities.

The analysis of the municipalities consisted of grouping data involves the variables Expenditure by Function of Government, General Health Expenditure, Hospital Care and Primary Care.

This research is justified by the complexity of public health financing in Brazil, which involves shared responsibility among the federal, state, and municipal governments through the social security budget. However, the allocation of public health resources often prioritizes political interests over the specific needs of municipalities across diverse regions, leading to a violation of constitutional principles intended to ensure equal rights for all citizens. Consequently, many municipalities face significant challenges due to the unequal distribution of resources, which tends to favor economically active regions.

The proposed computational analysis, through improved information management, offers a promising tool to address this issue and foster more consistent discussions on the equitable distribution

of health resources among the three levels of government. The cluster analysis methodology presented in this study groups municipalities with similar economic conditions but differing patterns of public health spending. Technology plays a crucial role in this process by providing data that can guide municipal public managers in resource negotiations at higher government levels. While clustering is an intuitive task for humans, the complexity increases with the number of instances, necessitating computerized methods for effective and accurate analysis. It is important to note that technology complements rather than replaces the human element, enhancing public management, resource utilization, and public health outcomes.

The research is theoretically grounded in information technology as a support tool for the decision-making process of Brazilian public managers, aiming to optimize and influence the quality of strategic analyses and promote safer, more reliable decisions. The study is structured into four sections, in addition to the introduction. The second section examines the consolidation and regulation of the Unified Health System (SUS) to understand the current context of health spending in Brazilian municipalities and the complexities involved in resource management. The third section details the methodology, which employs a quantitative and documentary approach to analyze health expenditures in Brazilian municipalities from 2004 to 2019. The fourth section presents the analysis and discussion of the results. Finally, the study concludes by reflecting on the use of computational intelligence to analyze health expenditures in Brazilian municipalities with populations of 100,000 or more, using complete data series for the specified timeframe.

THEORETICAL FRAMEWORK

Brazil has built and consolidated one of the largest public health systems in the world since the 20th century. Although the SUS has significantly expanded access to health, there are still significant inequalities between the different regions of the country that need to be addressed to ensure equity in healthcare for the population (CASTRO *et al*., 2019).In any case, the Unified Health System (Sistema Único de Saúde - SUS) has advanced the country's social policies, allowing millions of previously uninsured Brazilians to access health services (ARAUJO *et al*., 2022).

The Federal Constitution of 1988 in Art. 196, §1 ensures that while the responsibility of public health for the care of all in a universal character is shared between the Union, the States, the Federal District and the Municipalities, in addition to other sources, the overload is perceived to be higher in the municipalities (BRASIL, 1988).

The complexity of financing and disparities in the healthcare system affects not only Brazil but also other countries such as Canada, France, Germany, and Great Britain. Brown (2003) states that the challenges faced by these countries correspond to increases in healthcare costs due to an aging population, the sustainability of financing due to economic and social pressures, and inequalities in coverage in different regions or geographical areas.

Therefore, from this perspective, the municipalization of health care, as part of the decentralization process imposed by the Federal Constitution of 1988, has brought to the municipalities the responsibility that weighs the difficulties of health practices, while incorporating, however, the concepts of democratization, universality, equity, and comprehensiveness of care among the Brazilian population.

Primary Care serves as the entry point to the Unified Health System (SUS), organized as a collection of health initiatives shaped by democratic, participatory management, and sanitary practices. This collaborative approach involves teamwork and is targeted at populations within clearly defined territorial boundaries. These populations, in assuming sanitary responsibility, take into account the unique dynamics of the territory in which they reside (MINISTÉRIO DA SAÚDE, 2006).

Among the programs that make up the primary care network, there is the Family Health Strategy (FHS), which services users not only within their Health Unit but also at home in places in their territory when the essentiality of a visit to the health center is verified by the efficacy of health care progress (MINISTÉRIO DA SAÚDE, 2011). Efficiency refers to the capacity of the system to function by considering the lowest costs without sacrificing results to obtain, as much as possible, the best cost-effectiveness (MBAU *et al.*, 2022).

In this sense, municipalities play a key role in providing this service since the objective of the program is focused on disease prevention and preventing queues in hospitals by offering users the condition of first contact with the SUS.

In accordance with Ordinance 3,390 issued on December 30, 2013, hospitals offering services within the Unified Health System (SUS) are designated as a singular point or a collection of points of care. Their mission and care profile are specifically outlined based on the demographic and epidemiological features of the population within a well-defined territorial jurisdiction. Access to services is regulated, and care is provided either through referenced channels or in response to spontaneous demand. Despite all these efforts produced in Brazil, it can be said that the country faces serious challenges in maintaining the balance of public spending, necessary for the implementation of social health policies being, perhaps, considered as classic fields of social welfare on behalf of the population. From there, countries like those that make up the BRICS argue that nations can improve the

health of the population and reduce diseases by encouraging healthy lifestyle habits (JAKOVLJEVIC, *et al*. 2019). In turn, public spending is defined by functions, subfunctions, projects and activities according to the Ministry of Budget and Management Ordinance (MOG - 42/99), along with government programs. As described in this ordinance for the functions of government referred to in Art. 2 - Item I of Law 4,320 of May 4, 1964, it represents the highest level of aggregation among the various areas of expenditure that fall within the public sector. The subfunctions represent a partition of these functions, aggregating a certain subset of public sector expenditure.

Based on the aforementioned legislation, Ostrom and Ostrom (2019), Nicholson-Crotty *et al*., (2021), brings as a concept of government programs, the strategic tools that aim to meet the needs of a community, resulting in economic and social well-being.

Returning to the provisions of Ordinance 42/99, coupled with government programs to the aforementioned norm, it also conceptualizes projects and activities as programming instruments to achieve program objectives, involving operations that are limited in time or continuous and permanent, which result in a product that is necessary for the maintenance, expansion or improvement of government action, respectively.

Based on these concepts established by the legal norm, Popescu *et al*. (2021) defines public expenditures as those made in the short or long term to improve the lives of people. The benefits of public spending for the implementation of public policies generate economic growth, in addition to the promotion and social protection of an entire population (ZOUHAR *et al*., 2021). Government effectiveness plays a crucial role in mediating this relationship, amplifying the growth effects of social spending (COORAY; NAM, 2024).

Thus, public spending is understood as being all sorts of amounts spent by the union, state or municipalities to fund the public services that are provided to implement public policies while, however, exerting impacts on the economy in general. Therefore, public spending materializes through the expenditures of public entities.

MATERIALS AND METHODS

Method

The approach adopted in the present study was characterized as quantitative and documentary, drawing mainly on the results of expenditures made in Brazilian municipalities, in digital format, which relate o the health government function.

We conducted a cluster analysis with the objective of identifying municipalities that exhibited similar characteristics in terms of health expenditures and different economic characteristics, facilitating the identification of common patterns and trends among them. To this end, the steps highlighted by Garcia-Dias (2020) were followed, namely: (1) Selection of the characteristics to be used for grouping; (2) choice of the similarity metric; (3) performing the clustering using a specific clustering algorithm; (4) validation and evaluation of the generated clustering.

In step 1, the variables were used Expenditures per Government Function, Hospital Care, Primary Care, and General Health Expenditures, and the combinations between the variables studied were performed. The similarity metric used was the Euclidean distance. For clustering, the k-means method was used due to its simplicity, low computational complexity, and its wide acceptance in many domains for solving clustering problems (IKOTUN, 2023). In the validation stage as well as in choosing the number of groups, we used the silhouette index (ROUSSEEUW, 1987).

The characteristics were grouped to verify the existence of correlation among them in the following manner:1) general health expenditures in relation to expenditures per government function; 2) hospital care in relation to general expenditures; 3) primary care in relation to general expenditures; 4) hospital care in relation to expenditures per government function; and 5) primary care in relation to expenditures per government function.

All experiments were performed with the R statistical software package (R Foundation for Statistical Computing, Vienna, Austria), version 3.3.3 and the clusterCrit package to compute the Silhouette values, and the Cluster package to perform the clustering. We chose to use the R software because it is free, covers many statistical techniques and data analysis, and has been successfully used by many researchers in various research studies such SubtypeDrug: a software package for prioritization of candidate cancer subtype-specific drugs (HAN *et al*., 2021); Clustering analysis and machine learning algorithms in the prediction of dietary patterns: Cross-sectional results of the Brazilian Longitudinal Study of Adult Health (ELSA-Brazil), (SILVA *et al*., 2022); Comparison of cervical cancer screening results among public and private services in Brazil (BISPO PEREIRA *et al*., 2022).

Data acquisition

The data analyzed in this study are sourced from the Brazilian Finance (Finbra) database, compiled from the National Treasury Secretariat's website. A recent study by Silva *et al*. (2023) examined the (Im)Precision of municipal budgets, analyzing data to assess budget accuracy and classify budgets as more or less precise.

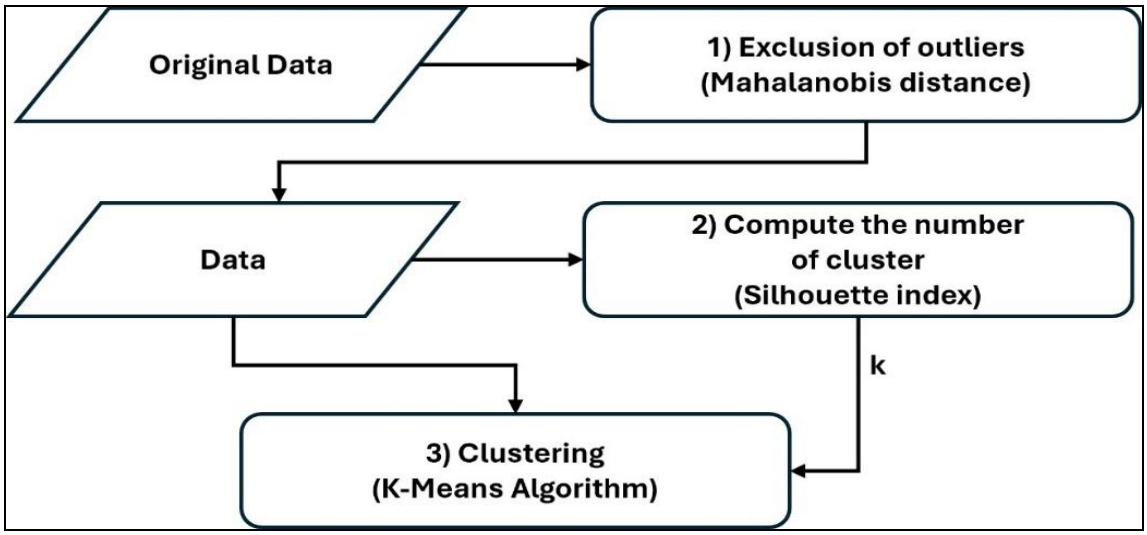
For the specific period evaluated in this study (2004 to 2019), data were obtained directly from the application "RMM DBHiper: Public Spending and Indicators of Effectiveness and Efficiency in Social Areas-Version 2.3.02-25" (RMM, 2020). The Finbra database is structured according to the Plan of Accounts Applied to the Public Sector (PCASP) as defined by the National Treasury Secretariat (2020). A sample of 117 Brazilian municipalities with an average population of at least 100,000 inhabitants and complete data for the analysis period was selected. Additionally, the gross domestic product (GDP) per capita for each municipality, based on 2017 data published in 2019 by the Institute of Geography and Statistics (IBGE, 2021), served as a complementary basis for analysis.

The data were adjusted for inflation using the Consumer Price Index-Broad (CPI-A), with January of each year as the reference month for determining the respective inflation index number. Inflation adjustments brought the analyzed period's values to current terms, specifically January 2019, by accounting for historical values on a year-by-year basis.

Data analysis procedures

The grouping of data consisted of dividing n instances of data into k groups so that the instances of the same group were more similar than instances of different groups (SCHAEFFER, 2007). Fig. 1 presents the computational intelligence approach that was used in performing the data groupings. The first step consists in the indication of municipalities considered atypical confirm this hypothesis average, and then we exclude these municipalities from the analyses performed. Atypical values generally interfere in the result of the grouping (GAO *et al*., 2023).

Figure 1 - General flowchart of the Computational Intelligence approach used



Source: Self elaboration.

The reduced data set (after eliminating atypical municipalities) was used to determine the optimal amount of clusters by measuring the Silhouette index. The parameter k represents the number of groups into which the data will be divided and should be provided as input to the clustering algorithm. In this step, the value of k varied from 2 to 10 and we chose the k related to the highest value of the index. The Silhouette index measures the quality of the clustering based on the proximity between instances of the same group and the distance of instances of a group to the closest group, and the higher its value, the better the clustering (GARCIA-DIAS, 2020). The Silhouette (Sil) index is calculated by equation.

$$S_{il} = \frac{\sum_{j=1}^{k} S_j}{k} \quad (1)$$

Where Sj is calculated by equation:

$$S = \frac{\sum_{i=j}^{N} S_{(vi)}}{N_I} \quad (2)$$

And S(v_i) is given by:

$$S(v_i) = \frac{d(v_i, C_h) - d(v_i, c_h)}{max(d(v_i, C_h) - d(v_i, c_j)} \quad (3)$$

In (3), vi represents the data instance, C_j the group to which vi belongs, C_h is the group closest to vi. The function d (x, y) measures the Euclidean distance between data instances x and y. The term N is the number of data instances in each group and k represents the number of groups. In the clustering step, the K-means method was used to search for a set of k vectors (centers of the groups) to represent the groups. After the search, each data instance is associated with the most similar group according to some similarity measure, e.g., Euclidean distance to the cluster center. The process of searching for the centers occurs as follows:

1. K randomly computed centers are created.
2. Data instances are associated with the closest center.
3. The centers are recalculated, being the midpoint of all instances associated with them.
4. Repeats steps 2 and 3, until there are no changes in the cluster configuration from one interaction to the next.

Ultimately, an in-depth and comprehensive statistical analysis was conducted on the researched variables. This analysis provides valuable insights and enhances our understanding of the underlying patterns and trends, offering a robust foundation for further exploration and discussion.

RESULTS AND DISCUSSION

Table 1 shows that only the expenses related to Hospital Care in relation to General Health Expenditure and Expenditure by Function of Government in relation to General Health Expenditure have a strong and moderate correlation, respectively. It is noteworthy that the calculations made to reach this conclusion involved all the municipalities of the sample together.

Table 1 - Linear correlation of health spending between the variables studied

Description	Correlation Coeficiente	Classification
Hospital Care/General Health Expenditure	0,88	Strong
Primary Care/General Health Expenditure	0,31	Weak
Expenditure by Function of Government/Hospital Care	0,60	Moderate
Expenditure by Function of Government/Primary Care	0,35	Weak
Expenditure by Function of Government/General Health expenditure	0,78	Strong

Source: Self elaboration.

Similarities between Municipal Public Health Expenditures

Similarity of public spending in Brazilian municipalities was determined through the creation of clusters involving variables such as Expenditure by Function of Government, Hospital Assistance, Primary Care and General Health Expenditure. The average total involving the four variables researched represents R$ 468,653.00 (Four hundred and sixty-eight thousand, six hundred and fifty-three reais), 69% of which is related to Expense by Government Function, Hospital Care (9%), Basic Care (5%), and General Health Expenses (17%).

Expenditure by Function of Government in Relation to General Health Expenditure

The technique that we used formed three groups that represent the similarities in average per capita spending, grouped using the variables General Health Expenditure in relation to Expenditure by Function of Government (Table 2A, Table 2B and Table 2C). For clarification purposes, according to the Ministry of Budget and Management Ordinance (MOG, 42/1999), government functions represent

the highest level of aggregation of the various expenditure areas that are the responsibility of the public sector.

The population of the municipalities, Group 1, benefited more in terms of the application of resources per capita than Group 2 when observing the two focal items. When analyzing this result, the economic situation of the first group was more attractive than the second when verifying the per capita values of the gross domestic product of each municipality. It should be noted that of the 30 municipalities in the first group, 43% have GDP (per capita) of less than R$50.00; in the second, 96% are in this same condition, which demonstrates a level of financial inequality between them. This means that all the wealth produced in these municipalities influences its collection and consequently, the Expenditure by Function of Government, since there must be a balance between the revenue collected and the expenditure made according to Law 4.320 of March 17, 1964.

Table 2A - Expenditure by Government Function in relation to General Health Expenditure for Group 1 with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000	Municipality (State)	GDP/R$ 1.000
Praia Grande (SP), Palmas (TO), Campo Grande (MS), Belo Horizonte (MG), Araras (SP), Florianópolis (SC), Itabira (MG), Curitiba (PR), Americana (SP), Caxias do Sul (RS), Blumenau (SC), Sorocaba (SP), Porto Alegre (RS), Campinas (SP), Rio de Janeiro (RJ), Ribeirão Preto (SP)	22 - 50	São Bernardo do Campo (SP), Betim (MG), Niterói (RJ), Canoas (RS), Piracicaba (SP), Vitória (ES), São José dos Campos (SP), Indaiatuba (SP), São Paulo (SP), Resende (RJ), Camaçari (BA), Parauapebas (PA), Jundiaí (SP), Itajaí (SC)	52-105
Interval (Expenditure by Government Function): 3.252 – 5.762 Interval (General Health Expenditure): 598 – 1.166 Interval (GDP/R$ 1.000) 22 – 105			

Source: Self elaboration.

Especially in relation to general health spending, it was evident that there is no correlation of these with GDP (per capita). However, when verifying the economic situation of the municipalities in Group 1, the average per capita values were higher than those of Group 2. The system also created Group 3, formed by the municipalities of Rio das Ostras (RJ) and São Caetano do Sul (SP), which were treated as outliers. It was observed that these values diverged significantly from the others. The reason for this discrepancy lies in the elasticity of spending, sensitive to cyclical movements of per capita income, in this case, of the municipalities (LAGO-PEÑAS *et al.*, 2013). This situation is atypical when considering all the other municipalities in the sample, both in relation to the amount spent by government function and general health expenditures.

Returning to Groups 1 and 2, their results may refer to two possible situations. First, they are due to the increase or decrease in tax revenue influenced by the wealth produced in the municipalities; in this case, it is necessary to highlight the discrepancy in average GDP (per capita) between the two groups analyzed. In addition, the municipalities in Group 1 may be applying resources in addition to the 15% of the proceeds of their collection of some taxes that were contemplated in the calculation, a perfectly positive situation determined by Art. 77 - Item III of the Federal Constitution of 1988.

Table 2B - Expenditure by Government Function in relation to General Health Expenditure for Group 2 with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000	Municipality (State)	GDP/R$ 1.000
São José de Ribamar (MA), Ribeirão das Neves (MG), Crato (CE), Paulista (PE), Parnaíba (PI), Viamão (RS), São Vicente (SP), Coronel Fabriciano (MG), São Mateus (ES), Teófilo OtonI (MG), Garanhuns (PE), Arapiraca (AL), Sabará (MG), Vitória da Conquista (BA), Porto Seguro (BA), Itapecerica da Serra (SP), Muriaé (MG), Jaboatão dos Guararapes (PE), Barbacena (MG), Açailândia (MA), Belém (PA), Passos (MG), Governador Valadares (MG), Nova Iguaçu (RJ), Mossoró (RN), Campina Grande (PB), Maceió (AL), Igarassu (PE), Feira de Santana (BA), Montes Claros (MG), Teresina (PI), Alagoinhas (BA), Cachoeiro de Itapemirim (ES), Ji-Paraná (RO), Fortaleza (CE), João Pessoa (PB), Ribeirão Pires (SP), Aracaju (SE), Divinópolis (MG), Imperatriz (MA),	11-27	Birigui (SP), Colatina (ES), Franca (SP), Boa Vista (RR), São Luís (MA), Mogi Guaçu (SP), Juiz de Fora (MG), Várzea Grande (MT), Teresópolis (RJ), Patos de Minas (MG), Umuarama (PR), Lages (SC), Marabá (PA), Lauro de Freitas (BA), Mogi das Cruzes (SP), Londrina (PR), Presidente Prudente (SP), Manaus (AM), Novo Hamburgo (RS), Sete Lagoas (MG), Mauá (SP), Araçatuba (SE), Poá (SP), São José do Rio Preto (SP), Serra (ES), Maracanaú (CE), Anápolis (GO), Dourados (MS), Guarulhos (SP), Maringá (PR), Sinop (MT), Chapecó (SC), Ponta Grossa (PR), São Carlos (SP), Pindamonhangaba (SP), Rio Grande (RS), Embu das Artes (SP), Atibaia (SP), Itu (SP), Brusque (SC), Joinville (SC), Itatiba (SP), Foz do Iguaçu (PR), Santa Cruz do Sul (RS), São José dos Pinhais (PR)	29-75
Interval (Expenditure by Government Function): 3.252 – 5.762 Interval (General Health Expenditure): 598 – 1.166 Interval (GDP/R$ 1.000) 22 - 105			

Source: Self elaboration.

It is important to emphasize that the noncompliance to this legislation by the other spheres of government (Federal and State) in relation to the transfer of health resources to the municipalities may be being harmed; however, this assumes the responsibility of the care for all in its existing demands, financially compromising other important social areas such as education, social assistance, security, and consequently the well-being of each community.

Table 2C - Expenditure by Government Function in relation to General Health Expenditure for Group 3 with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000
Rio das Ostras (RJ)	41
São Caetano do Sul (SP)	83
Interval (Expenditure by Government Function): 8.439 – 8.637 Interval (General Health Expenditure): 1.376 - 1.746 Interval (GDP/R$ 1.000) 41-83	

Source: Self elaboration.

Hospital Care in Relation to General Health Expenditure

Having generated two groups during the analysis of these variables, the costs of hospital care are shown to varied proportionally in relation to general health costs according to the municipalities grouped (Table 3A, Table 3B). The reciprocal is not true when the clusters are formed while considering the per capita means of the gross domestic product with the two variables studied. The average GDP of the municipalities in Group 2 is higher than the average of those calculated in Group 1.

The municipalities grouped in Group 2 represent a better scenario in terms of health care coverage than Group 1. This situation shows the application of a greater volume of resources in Hospital Care, perhaps due to the better performance in relation to the economic situation, measured by GDP; otherwise, they may be making the mistake of not strengthening primary care, which aims to offer society primary care and, consequently, assistance aimed at disease prevention.

Table 3A - Hospital Care in relation to General Health Expenditure for Group 1 with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000	Municipality (State)	GDP/R$ 1.000
Açailândia (MA) Alagoinhas (BA) Belém (PA) Cachoeiro de Itapemirim (ES) Campina Grande (PB) Coronel Fabriciano (MG) Crato (CE) Feira de Santana (BA) Garanhuns (PE) Governador Valadares (MG) Igarassu (PE) Itapecerica da Serra (SP) Jaboatão dos Guararapes (PE) Ji-Paraná (RO) Maceió (AL) Mossoró (RN) Muriaé (MG) Nova Iguaçu (RJ) Parnaíba (PI) Passos (MG) Paulista (PE) Porto Seguro (BA) Ribeirão das Neves (MG) Sabará (MG) São José de Ribamar (MA) São Mateus (ES) São Vicente (SP) Viamão (RS),	11-23	Vitória da Conquista (BA), Araçatuba (SE) Atibaia (SP) Birigui (SP) Boa Vista (RR) Brusque (SC) Camaçari (BA) Colatina (ES)Embu das Artes (SP) Florianópolis (SC) Franca (SP) Itu (SP) Itatiba (SP) Lages (SC) Lauro de Freitas (BA) Manaus (AM) Marabá (PA) Mauá (SP) Mogi das Cruzes (SP) Novo Hamburgo (RS) Palmas (TO) Ponta Grossa (PR) Presidente Prudente (SP) Ribeirão Pires (SP) Rio Grande (RS) São José do Rio Preto (SP) São Paulo (SP) Serra (ES) Sinop (MT) Várzea Grande (MT) Vitória (ES)	25-79
Interval (Hospital Care): 13 – 399 Interval (General Health Expenditure): 203 – 823 Interval (GDP) 11-79			

Source: Self elaboration.

It is hoped that this hypothesis can be confirmed through the analysis of the variables primary care in relation to general expenses in the next topic. The idea of investing in primary care is reinforced by Ordinance 3,390 of December 30, 2013, which states that hospitals, as members of the Health Care Network (HCN), will act in conjunction with primary health care because of the latter's role as coordinator of care and ordinator of the HCN, following the dictates of the Ordinance 2,488/GM/MS of October 21, 2011, which approved the National Policy for Primary Care (PNAB).

It is noteworthy that while spending more on hospital care per capita is healthy, this condition may contribute to neglecting other areas of health and government in addition to failing to meet the basic objective of avoiding or reducing spending on individuals in a hospital.

Table 3B - Hospital Care in relation to General Health Expenditure for Group 2 with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000	Municipality (State)	GDP/R$ 1.000
Teófilo Otoni (MG), Arapiraca (AL), Barbacena (MG), Praia Grande (SP), Montes Claros (MG), Teresina (PI), Fortaleza (CE), João Pessoa (PB), Aracaju (SE), Divinópolis (MG), Imperatriz (MA), São Luís (MA), Mogi Guaçu (SP), Juiz de Fora (MG), Teresópolis (RJ), Patos de Minas (MG), Umuarama (PR), Campo Grande (MS), Londrina (PR), Sete Lagoas (MG), Belo Horizonte (MG), Poá (SP), Maracanaú (CE), Anápolis (GO), Dourados (MS), Araras (SP), Rio das Ostras (RJ), Guarulhos (SP), Maringá (PR), Chapecó (SC),	17-42	São Carlos (SP), Pindamonhangaba (SP), Itabira (MG), Curitiba (PR), Americana (SP), Caxias do Sul (RS), Blumenau (SC), Joinville (SC), Sorocaba (SP), Porto Alegre (RS), Campinas (SP), Foz do Iguaçu (PR), Rio de Janeiro (RJ), Ribeirão Preto (SP), São Bernardo do Campo (SP), Betim (MG), Niterói (RJ), Canoas (RS), Piracicaba (SP), São José dos Campos (SP), Indaiatuba (SP), Resende (RJ), Santa Cruz do Sul (RS), São José dos Pinhais (PR), São Caetano do Sul (SP), Parauapebas (PA), Jundiaí (SP), Itajaí (SC)	43-105
Interval (Hospital Care): 231- 1.522 Interval (General Health Expenditure): 641 – 1.746 Interval (GDP) 17-105			

Source: Self elaboration.

According to Bambra (2022), one of the primary objectives of a health system is to enhance the safeguarding of individuals health. This involves addressing the population's expectations concerning their healthcare conditions, ultimately aiming to diminish social inequalities.

Based on this premise, it is evident that spending more on health may be a viable alternative for the better quality of life of a population, not necessarily through treatment but prevention.

Primary Care in Relation to General Health Expenditure

The grouping of municipalities performed in Primary Care in relation to General Health Expenditure triggered clusters forming 7 distinct groups (Table 4A, Table 4B, Table 4C, Table 4D, Table 4E, Table 4F and Table 4G), demonstrating a greater polarization of spending on health in the primary care program. When researching the hypothesis raised in the previous section about spending on hospital care, the aforementioned tables that group the municipalities according to both primary care and hospital care are similar, reinforcing the thesis that a lack of investment in primary care may be responsible for the increase in per capita hospital care spending. Of the 117 municipalities studied, 75% have an average per capita higher than that applied in hospital care, and only 25% do not follow this rule.

Table 4A - Primary Care in relation to General Health Expenditure for Group 1 with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000	Municipality (State)	GDP/R$ 1.000
Crato (CE), São Vicente (SP), Vitória da Conquista (BA), Belém (PA), Governador Valadares (MG), Mossoró (RN), Campina Grande (PB), Maceió (AL), Feira de Santana (BA), Ribeirão Pires (SP), Birigui (SP), Colatina (ES), Franca (SP), Boa Vista (RR), Palmas (TO), Lages (SC), Marabá (PA), Mogi das Cruzes (SP), Presidente Prudente (SP)	12-32	Mauá (SP), Araçatuba (SE), Poá (SP), São José do Rio Preto (SP), Anápolis (GO), Araras (SP), Florianópolis (SC), Guarulhos (SP), Sinop (MT), Atibaia (SP), Itu (SP), Brusque (SC), Itatiba (SP), Rio de Janeiro (RJ), São José dos Pinhais (PR)	34-75
Interval (-Primary Care): 75 – 394 Interval (General Health Expenditure): 495 – 699 Interval (GDP/R$ 1.000) 12-75			

Source: Self elaboration.

Table 4B - Primary Care in relation to General Health Expenditure for Group 2 with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000
Rio das Ostras (RJ)	41
Primary Care: 313 General Health Expenditure: 1.376	

Source: Self elaboration.

Table 4C - Primary Care in relation to General Health Expenditure for Group III with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000
São José de Ribamar (MA), Ribeirão das Neves (MG), Paulista (PE), Parnaíba (PI), Viamão (RS), Coronel Fabriciano (MG), São Mateus (ES), Garanhuns (PE), Sabará (MG), Porto Seguro (BA), Itapecerica da Serra (SP), Muriaé (MG), Jaboatão dos Guararapes (PE), Açailândia (MA), Passos (MG), Nova Iguaçu (RJ), Igarassu (PE), Alagoinhas (BA), Cachoeiro de Itapemirim (ES), Ji-Paraná (RO), Várzea Grande (MT), Lauro de Freitas (BA), Manaus (AM), Serra (ES), Ponta Grossa (PR), Rio Grande (RS), Embu das Artes (SP)	11-44
Interval (Primary Care): 38 – 237 Interval (General Health Expenditure): 203 – 503 Interval (GDP/R$ 1.000) 11-44	

Source: Self elaboration.

Table 4D - Primary Care in relation to General Health Expenditure for Group IV with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000
Teófilo Otoni (MG), Arapiraca (AL), Barbacena (MG), Praia Grande (SP), Montes Claros (MG), Fortaleza (CE), João Pessoa (PB), Aracaju (SE), Divinópolis (MG), Imperatriz (MA), São Luís (MA), Mogi Guaçu (SP), Teresópolis (RJ), Patos de Minas (MG), Umuarama (PR), Sete Lagoas (MG), Maracanaú (CE), São Carlos (SP), Pindamonhangaba (SP), Curitiba (PR), Americana (SP), Caxias do Sul (RS), Sorocaba (SP), Foz do Iguaçu (PR), Niterói (RJ), Piracicaba (SP), Vitória (ES), Indaiatuba (SP), São Paulo (SP), Camaçari (BA)	17-79
Interval (Primary Care) 45 – 342 Interval (General Health Expenditure): 694-885 Interval (GDP): 17-79	

Source: Self elaboration.

Table 4E - Primary Care in relation to General Health Expenditure for Group V with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000
Novo Hamburgo (RS), Chapecó (SC), Blumenau (SC), Ribeirão Preto (SP)	35-52
Interval (Primary Care): 455 – 481 Interval (General Health Expenditure): 767 – 979 Interval (GDP/R$ 1.000) 35-52	

Source: Self elaboration.

Table 4F - Primary Care in relation to General Health Expenditure for Group V with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000
Teresina (PI), Juiz de Fora (MG), Campo Grande (MS), Londrina (PR), Belo Horizonte (MG), Dourados (MS), Maringá (PR), Itabira (MG), Joinville (SC), Porto Alegre (RS), Campinas (SP), São Bernardo do Campo (SP), Betim (MG), Canoas (RS), Resende (RJ), Santa Cruz do Sul (RS), Parauapebas (PA), Jundiaí (SP).	23-102
Interval (Primary Care): 102 – 310 Interval (General Health Expenditure): 904 – 1.166 Interval (GDP/R$ 1.000) 23-102	

Source: Self elaboration.

Table 4G - Primary Care in relation to General Health Expenditure for Group VII with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000
São José dos Campos (SP), São Caetano do Sul (SP), Itajaí (SC)	57-105
Interval (Primary Care): 164 – 627 Interval (General Health Expenditure): 946 – 1.746 Interval (GDP/R$ 1.000) 57-105	

Source: Self elaboration.

Barros *et al*. (2022) confirm this hypothesis when they state, through a study conducted from 2008 to 2019, that municipalities increased spending on primary care by 12% in average expenditures and expanded coverage. This reality among the grouping of municipalities may possibly be related to the insufficiency of health financing by other spheres of government in favor of the benefited municipalities.

This leads us to suggest that not every municipality has sufficient resources of its own to cover the deficiencies in resources imposed by the federal/state government, especially in hospital care.

According to Ordinance No. 2,436 of September 21, 2017, all spheres of government have the responsibility of ensuring universal, equitable and orderly access to SUS health actions and services to users.

It should be noted that the progress in the distribution of resources and financing of primary health care in Brazilian municipalities is indisputable and noticeable; however, this research shows that there is still much to advance in this discussion.

Expenditure by Function of Government in Relation to Hospital Care

With the use of the computational tool, it was possible to create clusters divided into 3 distinct groups, showing that the expenses incurred via hospital care have a moderate influence on those incurred by the total Government Functions if all municipalities are evaluated together. However, when performing the analysis of the clusters that formed, there was a change in this reality. The spending on hospital care in the municipalities in Group I is generally higher than that in Group II. This situation may be indicative of better fundraising in the first group, given that its average per capita is almost four times higher than the mean of the second group (Table 5A, Table 5B. and Table 5C).

According to Table 5A, the highlight of the first group is Parauapebas (PA) with the highest expenditure by government function, R$ 5,761.67, while Palmas (TO) presents the lowest, R$ 3,251.96. In the second group, Ribeirão das Neves (MG) has R$ 1,137.10 and Atibaia (SP) R$ 3,143.20. Hospital assistance expenditures varied significantly, and Florianópolis (SC) showed the lowest value - R$ 133.51. In this category, municipalities with high GDP per capita in Group 1 include Jundiaí (SP) and Itajaí (SC), with R$ 101.61 and R$ 104.87, respectively, indicating a more robust local economy, while Praia Grande (SP) has the lowest GDP per capita, R$ 21.95, which may represent local economic challenges.

Table 5A - Expenditure by Function of Government in relation to Hospital Care for Group I with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000
Praia Grande (SP), Palmas (TO), Campo Grande (MS), Belo Horizonte (MG), Araras (SP), Florianópolis (SC), Itabira (MG), Curitiba (PR), Americana (SP), Caxias do Sul (RS), Blumenau (SC), Sorocaba (SP), Porto Alegre (RS), Campinas (SP), Rio de Janeiro (RJ), Ribeirão Preto (SP), São Bernardo do Campo (SP), Betim (MG), Niterói (RJ), Canoa (RS), Piracicaba (SP), São José dos Campo (SP), Indaiatuba (SP), São Paulo (SP), Resende RJ), Camaçari (BA), Parauapebas (PA), Jundiaí (SP), Itajaí (SC)	22-105
Interval (Expenditure by Government Function): 3.252 – 5.762 Interval (Hospital Care): 134 – 803 Interval (GDP/R$ 1.000) 22-105	

Source: Self elaboration.

On the other hand, São Bernardo do Campo stands out in terms of investment (R$ 802.94 per capita), but with a much lower GDP per capita (R$ 54.34), followed by Jundiaí (SP) with R$ 757.67, contradicting the GDP logic.

When evaluating the data from Table 5B - Group II, it was observed that the municipalities with the highest GDP per capita were São Mateus (ES) and Rio Grande (RS), presenting a stronger economic base, allowing for greater revenue collection and potentially more investments in public health services. The city of São Mateus (ES), with an extremely high GDP per capita, has a relatively high expenditure by function, but the worst investment in hospital assistance may indicate a priority in areas other than health. Conversely, municipalities like Dourados (MS) have a lower GDP per capita but invest significantly in hospital assistance, possibly prioritizing health due to local needs.

Table 5B - Expenditure by Function of Government in relation to Hospital Care for Group II with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000	Municipality (State)	GDP/R$ 1.000
Teófilo Otoni (MG), Montes Claros (MG), Juiz de Fora (MG), Barbacena (MG), Londrina (PR), Divinópolis (MG), Imperatriz (MA), Patos de Minas (MG), Crato (CE), Sete Lagoas (MG), Dourados (MS), Maringá (PR), Arapiraca (AL), Santa Cruz do Sul (RS), Fortaleza (CE), Feira de Santana (BA), Umuarama (PR), Teresina (PI), Campina Grande (PB), Foz do Iguaçu (PR), Maracanaú (CE), Ribeirão Pires (SP), São Carlos (SP), Nova Iguaçu (RJ) São Luís (MA), Franca (SP), João Pessoa (PB), Vitória da Conquista (BA), Anápolis (GO), Aracaju (SE), Maceió (AL), Joinville (SC), Passos (MG), Teresópolis (RJ), Chapecó (SC), São José dos Pinhais (PR), Pindamonhangaba (SP), Guarulhos (SP), Mogi Guaçu (SP), Itapecerica da Serra (SP), Ribeirão das Neves (MG), Mauá (SP), Governador Valadares (MG)	3-8	Belém (PA), Alagoinhas (BA),Ji-Paraná (RO), Sinop (MT), Poá (SP), Igarassu (PE), Açailândia (MA), Parnaíba (PI), Lages (SC), Brusque (SC), Itatiba (SP), Marabá (PA), Birigui (SP), Araçatuba (SE), Garanhuns (PE), Novo Hamburgo (RS), Colatina (ES), São José de Ribamar (MA), São José do Rio Preto (SP), Jaboatão dos Guararapes (PE), Atibaia (SP), Porto Seguro (BA), Itu (SP), Muriaé (MG), Ponta Grossa (PR), Mogi das Cruzes (SP), Boa Vista (RR), Paulista (PE), Manaus (AM), São Vicente (SP), Presidente Prudente (SP), Embu das Artes (SP), Mossoró (RN), Lauro de Freitas (BA), Coronel Fabriciano (MG), Sabará (MG), Várzea Grande (MT), Cachoeiro de Itapemirim (ES), Serra (ES), Viamão (RS), Rio Grande (RS), São Mateus (ES)	9-15
Interval (Expenditure by Government Function): 1.137 – 3.143 Interval (Hospital Care): 13 – 667 Interval (GDP/R$ 1.000) 3-15			

Source: Self elaboration.

Overall, there was a variation in GDP per capita among the evaluated municipalities, which may be indicative of significant economic inequalities, especially those contained in Group II. The study conducted by Santos Neto (2017) points out that when investments and financing in health become a governmental priority, per capita health can double, significantly increasing the quality of life of a population.

It is necessary to comment on the exception of the municipalities of Rio das Ostras (RJ), São Caetano do Sul (SP) and Vitória (ES) contained in Group III, which are considered outliers; however, these are treated as favorable and beneficial. When analyzing these data, specifically, in Table 5C, the per capita values of Expenditure by Function of Government in relation to hospital care in these municipalities significantly exceeded more than 40% of those described in Groups I and II, a considerable distortion of the values in relation to the others.

Table 5C - Expenditure by Function of Government in relation to Hospital Care for Group III with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000
Rio das Ostras (RJ), Vitória (ES), São Caetano do Sul (SP)	41-83
Interval (Expenditure by Government Function: 5.055 – 8.637 Interval (Hospital Care): 107 – 1.522 Interval (GDP/R$ 1.000) 41-83	

Source: Self elaboration.

Expenditure by Function of Government in Relation to Primary Care

Expenses by function represent the total expenditures in each unit that comprises the structure of municipalities, while primary care is an indicator of how much is being specifically invested in the first line of citizen care. According to the data presented in Table 6A – Group 1, the values applied in the studied categories are not influenced by GDP per capita, dismissing the narrative that the better the economic condition of the municipality, the greater the investment in primary care. From the 28 grouped municipalities, considering only those with a GDP per capita above R$ 50,000, only 7, or 11%, corresponding to São Bernardo do Campo (SP), São Paulo (SP), Jundiaí (SP), Indaiatuba (SP), Parauapebas (PA), and Ribeirão Preto (SP), invested more than R$ 200.00 (per capita) in Primary Care. The worst investment in primary care is in Piracicaba (MG), and the lowest GDP per capita (R$ 21,95) is in the municipality of Praia Grande (SP).

Table 6A - Expenditure by Function of Government in relation to Primary Care for Group I with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000
Americana (SP), Araras (SP), Belo Horizonte (MG), Betim (MG), Blumenau (SC), Camaçari (BA), Campinas (SP), Campo Grande (MS), Canoas (RS), Caxias do Sul (RS), Curitiba (PR), Florianópolis (SC) Indaiatuba (SP), Itabira (MG), Jundiaí (SP), Niterói (RJ), Palmas (TO), Parauapebas (PA), Piracicaba (SP), Porto Alegre (RS), Praia Grande (SP), Resende (RJ), Ribeirão Preto (SP), Rio de Janeiro (RJ), São Bernardo do Campo (SP), São Paulo (SP), Sorocaba (SP), Vitória (ES)	22-102
Interval (Expenditure by Function of Government): 3.252 – 5.762 Interval (Primary Care): 78 – 460 Interval (GDP/R$ 1.000) 22-102	

Source: Self elaboration.

On the other hand, when evaluating expenditures by government function, only Jundiaí (SP), with the highest GDP per capita (R$ 101,61), is among the top 5 investments in primary care, approaching R$ 5,000.00, followed by Itabira (MG), São Bernardo do Campo (SP), Vitória (ES), and Parauapebas (SP).

Therefore, in the analysis of these variables, it is concluded that there is no influence of per capita expenditures by Government Function on primary care (Table 6A and Table 6B). It should be noted that the same exceptionality was mentioned in the previous topic, but with some different municipalities (Table 6C, Group III, referring to the municipalities of Rio das Ostras (RJ), São Caetano

do Sul (SP), São José dos Campos (SP), and Itajaí (SC), which, despite being considered outliers, showed effective and decisive results regarding the use of public resources in the governmental function of health. According to Silva Marques (2023), investing in primary care can contribute to strengthening access to health, preventing diseases, promoting health, and consequently reducing future costs with treatments for more severe conditions. It is important to emphasize that the average GDP per capita of these last 4 mentioned municipalities exceeds the average of all other groups studied concerning these variables.

Table 6B - Expenditure by Function of Government in relation to Primary Care for Group II with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000	Municipality (State)	GDP/R$ 1.000
São José de Ribamar (MA), Ribeirão das Neves (MG), Crato (CE), Paulista (PE), Parnaíba (PI), Viamão (RS), São Vicente (SP), Coronel Fabriciano (MG), São Mateus (ES), Teófilo Otoni (MG), Garanhuns (PE), Arapiraca (AL), Sabará (MG), Vitória da Conquista (BA), Porto Seguro (BA), Itapecerica da Serra (SP), Muriaé (MG), Jaboatão dos Guararapes (PE), Barbacena (MG), Açailândia (MA), Belém (PA), Passos (MG), Governador Valadares (MG), Nova Iguaçu (RJ), Mossoró (RN), Campina Grande (PB), Maceió (AL), Igarassu (PE), Feira de Santana (BA), Montes Claros (MG), Teresina (PI), Alagoinhas (BA), Cachoeiro de Itapemirim (ES),Ji-Paraná (RO), Fortaleza (CE), João Pessoa (PB), Ribeirão Pires (SP), Aracaju (SE), Divinópolis (MG), Imperatriz (MA), Birigui (SP), Colatina (ES), Franca (SP),	11-27	Boa Vista (RR), São Luís (MA), Mogi Guaçu (SP), Juiz de Fora (MG), Várzea Grande (MT), Teresópolis (RJ), Patos de Minas (MG), Umuarama (PR), Lages (SC), Marabá (PA), Lauro de Freitas (BA), Mogi das Cruzes (SP), Londrina (PR), Presidente Prudente (SP), Manaus (AM), Novo Hamburgo (RS), Sete Lagoas (MG), Mauá (SP), Araçatuba (SE), Poá (SP), São José do Rio Preto (SP), Serra (ES), Maracanaú (CE), Anápolis (GO), Dourados (MS), Guarulhos (SP), Maringá (PR), Sinop (MT), Chapecó (SC), Ponta Grossa (PR), São Carlos (SP), Pindamonhangaba (SP), Rio Grande (RS), Embu das Artes (SP), Atibaia (SP), Itu (SP), Brusque (SC), Joinville (SC), Itatiba (SP), Foz do Iguaçu (PR), Santa Cruz do Sul (RS), São José dos Pinhais (PR	29-75
Interval (Expenditure by Function of Government): 1.137 – 3.143 Interval (Primary Care): 38 – 481 Interval (GDP/R$ 1.000) 11-75			

Source: Self elaboration.

Table 6C - Expenditure by Function of Government in relation to Primary Care for Group III with Amounts in R$ Per Capita

Municipality (State)	GDP/R$ 1.000
Rio das Ostras (RJ), São José dos Campos (SP), São Caetano do Sul (SP), Itajaí (SC)	41-105
Interval (Expenditure by Function of Government): 3.566 – 8.637 Interval (Primary Care): 164 – 627 Interval (GDP/R$ 1.000) 41-105	

Source: Self elaboration.

Statistical analysis of the variable surveyed

According to the data from Table 7A, it is possible to observe that the medians of expenditures by government function (2,758), general health expenditure (697), and 36.4, referring to GDP per capita, are lower than their means, resulting in an asymmetric data distribution influenced by the means themselves. The variability of the data is confirmed by the standard deviation and the Shapiro-Wilk

normality test, which showed a p-value < 0.001. This result may reflect significant differences in health policies and investment levels of municipalities across the different regions surveyed, greatly influencing the data.

Table 7A - Expenditure by Function of Government / General Health Expenditure

Description	Expenditure Function of Government	General Health Expenditure	GDP/R$ 1.000
Mean	2.758	697	36.4
Median	2.547	684	35
Standard Deviation	1.146	249	18.2
W de Shapiro-Wilk	0.811	0.967	0.897
p Shapiro-Wilk	<.001	0.005	<.001

Source: Self elaboration.

Furthermore, the Spearman coefficient was applied, as shown in Table 7B, to assess the level of correlation between the variables in pairs. Between expenditures by government function and general health expenditures, a strong and positive correlation was found, indicating that the expenditures have a direct behavior in the same proportionality. The p-value < 0.001 defines this correlation and considers it statistically significant, reinforcing the reliability of this relationship.

Table 7B - Expenditure by Function of Government / General Health Expenditure

Variable	Description	Function of Government	General Health Expenditure	GDP/R$ 1.000
Function of Government	Coefficient Spearman	—		
	p-value	—		
General Health Expenditure	Coefficient Spearman	0.749	—	
	p-value	<.001	—	
GDP/R$ 1.000	Coefficient Spearman	0.807***	0.602***	—
	p-value	<.001	<.001	—

Source: Self elaboration.
Note: * p < .05, ** p < .01, *** p < .001.

When comparing expenditures by government function and Gross Domestic Product (GDP), the correlation is even stronger, showing that the variables are associated. The better the economic situation of the municipalities, the greater the expenditures made in government functions (MELO JR., 2002).

On the other hand, when evaluating the correlation between General Health Expenditure and GDP, the result was positive, but not as strong as when analyzing the Expenditure of Government and Expenditure Function General Health.

Continuing the statistical analysis, the data available in Table 8A were examined, referring to Hospital Care Expenditure and General Health Expenditure. The data show averages of 344 for hospital care, 697 for general health expenditures, and 36.4 for GDP per capita, which exceeded the medians of 312, 684, and 35, respectively. The result indicates potential skewness in the data distribution,

confirmed by the Shapiro-Wilk Coefficient, as it showed a p-value <0.001 for hospital care and GDP per capita. Another confirmation of data dispersion was shown by the high standard deviation, particularly in hospital care (211) and general health expenditures (249), possibly due to the presence of outliers and the heterogeneity in the allocation of available resources in the evaluated municipalities.

Table 8A - Hospital Care Expenditure/General Health Expenditure

Description	Hospital Care Expenditure	General Health Expenditure	GDP/R$ 1.000
Mean	344	697	36.4
Median	312	684	35.0
Standard Deviation	211	249	18.2
W de Shapiro-Wilk	0.899	0.967	0.897
p Shapiro-Wilk	<.001	0.005	<.001

Source: Self elaboration.

Observing the Spearman Coefficient Table 8B, specifically regarding the variables Hospital Care Expenditure and General Health Expenditure, it was evident that there is a strong and significant correlation between them. Therefore, it can be said, according to the index of (0.852), that as general health expenditures increase, hospital care is also positively affected.

Table 8B - Hospital Care Expenditure/General Health Expenditure

Variable	Description	Hospital Care Expenditure	General Health Expenditure	GDP/R$ 1.000
Hospital Care Expenditure	Coefficient Spearman	—		
	p-value	—		
General Health Expenditure	Coefficient Spearman	0.852***	—	
	p-value	<.001	—	
GDP/R$ 1.000	Coefficient Spearman	0.379***	0.602***	—
	p-value	<.001	<.001	—

Source: Self elaboration.
Note: * p < .05, ** p < .01, *** p < .001.

On the other hand, when evaluating the results of Hospital Care and GDP per capita, a positive but moderate correlation is perceived. In this sense, the understanding is that the increase in GDP may influence, in some cases, the increase in hospital expenditures. Thus, considering the presented results, Meng (2022) argues that financial increases in health can meet a greater demand for quality health services in any society. Finally, general health expenditures and GDP presented a coefficient of 0.602, considered by the Spearman Coefficient as strong and significant.

In light of the above, it can be deduced that although economic growth contributes to greater investments in health, other factors, such as specific public health policies or governmental priorities, also play an important role in the provision of services offered to the population.

The results of the variables Primary Care Expenditure and General Health Expenditure, as described in Table 9A, showed means and medians of 207 and 184, respectively, indicating an asymmetric data distribution, possibly influenced by outliers affecting the mean. General health

expenditures have a mean of 697 and a median of 684, indicating a more balanced distribution, though still slightly asymmetric.

The variable GDP per capita had a mean of 36.4 and a median of 35.0, following the same pattern as the previously mentioned variables, albeit on a smaller scale. The standard deviation for primary care is 109, and for general health expenditures, it is 249, indicating a much larger proportion. These significant differences can be considered as consequences of how primary care is funded in different contexts. It is believed, based on the analysis of the results, that there are possible infrastructure issues in the health sector in the evaluated units, as well as a lack of adaptive policies that consider regional and contextual variations.

Table 9A - Primary Care Expenditure/General Health Expenditure

Description	Primary Care Expenditure	General Health Expenditure	GDP/R$ 1.000
Mean	207	697	36.4
Median	184	684	35.0
Standard Deviation	109	249	18.2
W de Shapiro-Wilk	0.911	0.967	0.897
p Shapiro-Wilk	<.001	0.005	<.001

Source: Self elaboration.

According to the data obtained by the Spearman Coefficient, shown in Table 9B, the results indicated that there are significant positive relationships between the analyzed variables. The moderate correlation between primary care expenditures and general health expenditures suggests that health investments tend to be distributed in a way that allows both sectors to develop concurrently. This correlation indicates that the economic growth of municipalities is associated with greater investments in the health sector, which may reflect better implementations of health policies in more prosperous economies (CEN *et al*., 2022).

Table 9B - Primary Care Expenditure/General Health Expenditure

Variable	Description	Primary Care Expenditure	General Health Expenditure	GDP/R$ 1.000
Primary Care Expenditure	Coefficient Spearman	—		
	p-value	—		
General Health Expenditure	Coefficient Spearman	0.329***	—	
	p-value	<.001	—	
GDP/R$ 1.000	Coefficient Spearman	0.330***	0.602***	—
	p-value	<.001	<.001	—

Source: Self elaboration.

The strong correlation between GDP per capita and general health expenditures highlights the importance of economic growth for health financing. As noted by Jack *et al*. (2009), the implementation of structured public policies is essential to increase investment in health through economic strengthening.

According to the data shown in Table 10A, which deals with Expenditure by Function of Government and Hospital Care Expenditure, it is noticeable that the means and medians of the respective variables are extremely divergent from each other, highlighting a considerable variability in the data. This condition is confirmed by the standard deviation values, and furthermore, all values determined by the Shapiro-Wilk coefficient are below 1. In this sense, the data do not follow a normal distribution, a condition similar to previously conducted statistical analyses.

Table 10A - Expenditure by Function of Government / Hospital Care Expenditure

Description	Function of Governament Expenditure	Hospital Care Expenditure	GDP/R$ 1.000
Mean	2.758	344	24.9
Median	2.547	312	11.0
Standard Deviation	1.146	211	28.5
W de Shapiro-Wilk	0.811	0.899	0.712
p Shapiro-Wilk	<.001	<.001	<.001

Source: Self elaboration.

When examining the variables involving Function of Government Expenditure, Hospital Care Expenditure, and GDP per capita, the correlations were moderate, indicating that the resources moved in one necessarily affect the others in the same proportion. The exception lies in Hospital Care Expenditure and GDP per capita, which showed a Spearman Coefficient of (-0.249), considered a weak negative correlation. Hence, it becomes evident that this spending behavior is inversely proportional; as GDP per capita increases, expenditures on primary care tend to decrease. The p-value of 0.007 indicates that this correlation is not statistically significant, and the strength of the correlation is low.

Table 10B - Expenditure by Function of Government / Hospital Care Expenditure

Variable	Description	Function of Governament Expenditure	Hospital Care Expenditure	GDP/R$ 1.000
Function of Governament Expenditure	Coefficient Spearman	—		
	p-value	—		
Hospital Care Expenditure	Coefficient Spearman	0.483***	—	
	p-value	<.001	—	
GDP/R$ 1.000	Coefficient Spearman	0.531***	-0.249**	—
	p-value	<.001	0.007	—

Source: Self elaboration.
Note: * p < .05, ** p < .01, *** p < .001 – gl – 115.

Rizvi (2019) contradicts this last result by stating that economic growth tends to increase when investments are made in health with the best institutions. Prioritizing health investments through solid institutions can establish continuous and inclusive economic growth.

The data presented in Table 11A show that the mean and median of Expenditure by Function of Government are extremely high compared to the means and medians of spending on Primary Care. This result leads us to deduce that the lack of investment in primary care may be contributing to the increase in hospital expenditures or there is a deficiency in the assistance or care provided to citizens. According

to the Brazilian Federal Constitution of 1988, adherence to the principles of the SUS (Unified Health System), universality, comprehensiveness, and equity, seeks to ensure that all citizens have access to quality health services, from prevention to treatment. Primary care is the preferred entry point to the health system and plays an important role in disease prevention and health promotion. When there is a lack of resources or inadequate investments in this area, health problems end up evolving into more serious conditions, which require more complex hospital interventions, thus increasing health sector expenses (SICILIANI, *et al*., 2009).

Table 11A - Expenditure Function of Government / Primary Care Expenditure

Description	Function of Governament Expenditure	Primary Care Expenditure	GDP/R$ 1.000
Mean	2758	207	36.4
Median	2547	184	35.0
Standard Deviation	1146	109	18.2
W de Shapiro-Wilk	0.811	0.911	0.897
p Shapiro-Wilk	<.001	<.001	<.001

Source: Self elaboration.

The aforementioned author further states that this deficiency can result in an overload of hospital services, leading to long waiting times, inadequate care, and ultimately, an increase in overall health costs. This assumption seemingly becomes a real case, given that when comparing expenditures on primary care with GDP, a weak correlation was found, even though it is positive. However, this condition can be attributed to several factors, including the unequal distribution of resources, the efficiency of health systems, or even the prioritization of other economic sectors to the detriment of health.

According to Table 11B, there is a moderate positive correlation between general government expenditure and hospital care expenditure. In contrast, when analyzing the variables hospital care and GDP per capita, the correlation was weak. The p-value indicates that increases in hospital care expenditure are related to increases or decreases in GDP per capita.

Table 11B - Expenditure by Function of Government / Primary Care Expenditure

Variable	Description	Function of Governament Expenditure	Primary Care Expenditure	GDP/R$ 1.000
Function of Governament Expenditure	Coefficient Spearman	—		
	p-value	—		
Primary Care Expenditure	Coefficient Spearman	0.488***	—	
	p-value	<.001	—	
GDP/R$ 1.000	Coefficient Spearman	0.807***	0.330***	—
	p-value	<.001	<.001	—

Source: Self elaboration.
Note: * p < .05, ** p < .01, *** p < .001 – gl – 115.

CONCLUSIONS

This study analyses the spending of Brazilian municipalities on health with an approach based on computational intelligence. When the variables Expenditure by Function of Government in relation to

General Health Expenditure were compared, the technique we used formed three groups, which showed that there are similarities between their average expenditure per capita and that the first group has a more attractive economic situation than the second, demonstrating a level of financial inequality between them.

Regarding general health spending, it is evident that there is correlation between these and GDP (per capita). In this relationship, the group of 3 municipalities was also formed, and these were considered outliers. Their values differed significantly from the others, and the reason for such discrepancy is related to their atypical economic situation if all other municipalities in the sample are considered in relation to their amount spent both per Government Function and General Health Expenditure.

When analyzing hospital care in relation to general health costs, a correlation was observed between these two variables, i.e., the costs of the former vary proportionally in relation to general health costs, although this finding is not supported when the clusters that were formed are considered regarding the averages per capita of the GDP of the two focal variables. The average GDP of the municipalities in Group II is higher than the average of those calculated in Group I, a situation that may be conditioned on the economic situation of the first group or lack of investment in primary care.

The study of primary care in relation to general health spending triggered clusters forming 7 distinct groups, demonstrating a greater polarization of health spending in the primary care program. An important aspect that deserves attention is the fact that the municipalities grouped based on primary care or hospital care are similar, reinforcing the thesis that a lack of investment in primary care may be responsible for the increase in per capita spending on hospital care. Of the 117 municipalities studied, 75% have an average per capita higher than that applied in hospital care, and 25% do not follow this rule. Subsequently, expenditures by government function in relation to hospital care were compared, and it was demonstrated that the expenses incurred with hospital care have a moderate influence on those incurred by the total Government Functions if all municipalities are evaluated together. Three groups were created, and the expenses of Group I were generally higher than those of Group II, which may be indicative of better fundraising. Group I has a per capita average of almost four times higher than the average of Group II. In this case, there were also municipalities such as Rio das Ostras (RJ), São Caetano do Sul (SP) and Vitória (ES) that were considered outliers*;* however, they should be treated as offering favorable and beneficial results in the situations assessed.

Finally, the analysis of expenditure by function of government in relation to primary care led to the conclusion that there is no influence of per capita spending on the focal variables. It is important to note that in this specific case of outliers such as Rio das Ostras (RJ), São Caetano do Sul (SP), São José

dos Campos (SP) and Itajaí (SC), regarding their GDP, the average per capita of these four municipalities exceeds the average of all the other focal groups in regard to these variables.

The results obtained and discussed in the research indicated that the use of Computational Intelligence techniques and, in this case, Cluster Analysis contributed substantially to the management of Brazilian public health resources; therefore, this study may subsidize the municipal governors and managers in their financial decisions, making it possible to compare the reality of the implementation of social health policies in the most diverse and different regions of the country and thus strengthen the debate of public managers with the Union and the States on the issue of the distribution of health resources among Brazilian municipalities.

Based on these results, it is concluded that computational intelligence combined with public health management may be the solution for public health administrators to have better control and transparency in their distribution of resources in Brazilian municipalities in addition to more reliable information for subsidizing internal decisions in each municipality and other spheres of government.

In this sense, further research is suggested that is not only based on other variable of the Brazilian health system, techniques and intersections but also extends to 2020 to explore the impacts of the COVID-19 pandemic.

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